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Remote Sensing Group (RSG), Optical Sciences Center (OSC) at the University of Arizona

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Contract Number: NAS5-31717

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Summary: Work by members of the RSG during the past six months consisted of Science Team support activities including the attendance at meetings related to MODIS and ASTER and submission of ATBDs and validation plans. Several members presented papers at the Denver SPIE meeting. The VNIR and SWIR Cross-Calibration Radiometers were used as part of a cross-calibration experiment looking at calibration sources being used for MTPE sensors. The spherical collector for the diffuse-to-global meter was completed. A field campaign was used to collect data to evaluate the angular response of the spherical collector and another campaign was used to test the completed prototype of the diffuse-to-global meter. A sensitivity analysis of vicarious calibration over dark targets was completed and a field campaign to Lake Tahoe was made to collect data in support of dark-target calibration work. The uniformity of the BRF meter was tested with our 40-inch SIS and the system was used to collect a BRF data set during a September campaign to White Sands. Data to evaluate the Cimel TIR radiometer were processed and presented to Cimel.

Introduction: This report contains nine sections. The first eight sections present different aspects of work performed under our contract. If appropriate, each section covers five areas; task objective, work accomplished, data/analysis/interpretations, anticipated future actions, and problems/corrective actions. The first eight sections are: 1) Science team support activities; 2) Cross-calibration radiometers; 3) Bi-directional reflectance distribution function (BRDF) meter; 4) Diffuse-to-global meter; 5) TIR field radiometer; 6) Calibration laboratory; 7) Algorithm and code development; and 8) Field experiments and equipment. The ninth section contains information related to faculty, staff, and students.

Science Team Support Activities: This section refers to all work performed in support of MODIS and ASTER team activities as well as work performed for other sensor teams. Over the past six months this included the attendance at team and other related meetings and completing assigned action items.

ASTER Activities: K. Thome and E. Zalewski attended the US ASTER Science Team meeting in Yokohama, Japan on December 2 where the two presented results from the joint, vicarious-calibration campaign held at Lunar Lake last June. The two also attended the Joint ASTER Science Team meeting in Yokohama from December 3-6. Zalewski co-chaired the radiometric calibration working group meeting. Thome presented the results of the Lunar Lake campaign to both the radiometric calibration working group and atmospheric correction working group. He also presented results of the SWAMP Land Workshop and ATBD reviews of the surface reflectance retrieval to the atmospheric correction working group. P. Slater, Thome and Zalewski attended the ATBD review of land products held at GSFC December 10 and 11.

Because of the considerable interest by the attendees at the joint ASTER Science Team meeting to convene a second joint, vicarious-calibration campaign, Zalewski chaired an ad hoc meeting to discuss this proposal. It was felt that because ASTER is unique in having two vicarious calibration teams - US and Japanese - some early decisions had to be reached in order to enable both teams to adequately prepare. During the ad hoc meeting it was decided to conduct the 1997 campaign during June at the Lunar Lake - Railroad Valley location and that during the prior week instrument cross-calibration checks will be done in a laboratory environment. At Goddard on December 12, Zalewski met with J. Butler, R. Barnes, and B. Guenther to convey the results of the Yokohama meeting and to plan for wider participation in the June campaign.

Slater submitted viewgraphs describing the validation plans, using vicarious calibration, for ASTER- and MODIS-derived top-of-atmosphere (TOA) radiances and Zalewski submitted Validation Plan documents for these two topics. Thome submitted a revised version of the ATBD for the atmospheric correction of ASTER to the EOS project science office and a revised version of the validation plan for the atmospheric correction to S. Hook of JPL. Thome sent comments to A. Schwarz of JPL regarding the ASTER Product Generation System Test Plan.

MODIS Activities: Zalewski attended the MCST ATBD IR Audit at Wisconsin on August 28 - 29. Slater and Zalewski attended the MCST ATBD Solar-reflective Audit at Goddard Space

Flight Center on September 5 - 6. S. Biggar attended a MODIS Quarterly Management Review at Goddard Space Flight Center September 18 and 19. Various test results were presented by SBRS with a discussion of how to interpret the results, if any tests should be redone, and whether it is possible to cancel some testing. Biggar investigated the scan mirror emissivity problem on MODIS as it relates to the thermal calibration. Slater and Zalewski attended a MODIS Calibration meeting on October 8 and the MODIS Science Team Meeting, October 9 - 11. They also attended the MODIS validation review in Columbia, Maryland on November 20 where Slater gave a 45 min presentation on the validation of MODIS top-of-atmosphere radiances using vicarious calibration.

<u>*Other EOS Related Activities:*</u> Biggar, Slater and Zalewski attended the EOS Calibration Meeting at Goddard Space Flight Center on 9 -11 July. Slater summarized the status of the calibration of the ASTER sensor subsystems, reviewed the First Joint Vicarious Calibration Field Campaign, gave a description of solar-radiation-based calibration (SRBC) including results of a recent comparison, made by Biggar, of SRBC and lamp-based calibrations of his VNIR radiometer, and lead a discussion on future plans for joint vicarious calibration activities. Biggar presented uncertainty analysis results for the SRBC approach and also presented data from the VNIR CCR.

Biggar, K. Scott, Slater, Thome, and Zalewski attended the Denver SPIE meeting August 5-7. Biggar served as session chair for an EOS session and presented a paper on the radiometric cross-calibration of HYDICE. Slater chaired a session on HYDICE characterization and gave a paper on the in-flight radiometric stability of HYDICE. Zalewski gave a paper on the laboratory and on-board calibration of HYDICE. Thome presented papers on a reflectance-based, vicarious calibration of HYDICE and a sensitivity analysis of the ASTER atmospheric correction. Scott presented results of a study of characteristics needed for in-flight cross-calibration of large footprint sensors.

Slater, Thome, and Zalewski attended a calibration workshop in Toulouse, France September 18-20 where they presented papers on SRBC, proposed calibration of VEGETATION by reference to SPOT-4, and the calibration of HYDICE, respectively. The three also attended the EUROPTO meeting in Taormina, Italy from September 23-26 where Thome presented a paper (with K. Arai of Saga University as first author) on the recent Lunar Lake experiment and results of last year's Lake Tahoe experiment (with R. Parada of RSG as lead author). Slater chaired two sessions on sensor calibration and was co-author of two papers.

Slater and Zalewski met with R. Barnes and J. Butler (GSFC), and C. Johnson (NIST), on October 7 to discuss plans for international collaboration in Vicarious Calibration field campaigns. Slater provided a list of about 60 invitees whom Butler subsequently emailed. During the week of December 2, Slater attended the CEOS/IVOS working group meeting on Calibration/Validation at DLR near Munich. He gave a talk on the validation of MODIS calibration emphasizing the desirability of international participation in field campaigns as being planned by Butler. Interest in participating was expressed by C. Mutlow (ATSR), P. Teillet (from CCRS) and E. Attema (from ESA). Thome attended the SWAMP meeting at GSFC on October 17 and 18. B. Crowther's paper describing the Monte Carlo simulation of integrating-sphere modeling used to design the collector for the diffuse-to-global meter appeared in *Applied Optics*.

<u>**Cross-Calibration Radiometers:**</u> This section describes work to design, fabricate, test, and calibrate a set of preflight cross-calibration radiometers (CCRs). These radiometers are to cover the wavelength region from 400 to 2500 nm. To accomplish this, two radiometers have been constructed, each optimized for a specific portion of the spectrum. They will have very low stray light and polarization responses, exhibit sharp, well-defined fields of view and spectral response profiles, and be ultrastable with respect to temperature and time. The radiometers have been used to provide an important independent calibration and cross-calibration of the calibration facilities used by the Phase C/D contractors.

Biggar and P. Spyak took part in cross-calibration experiments involving calibration sources for MTPE by traveling to Santa Barbara and Pasadena for measurements of the MODIS spherical integrating source (SIS) from August 12-14, the Landsat SIS on August 15, and the MISR SIS on August 17 and 19-21. Both radiometers performed well. Biggar and Spyak sent preliminary results of the cross-calibration experiments to C. Johnson of NIST. In November, the two also participated in a cross-calibration experiment in Japan of the ASTER calibration sources at NEC (VNIR) and MELCO (SWIR). Biggar used the VNIR CCR to measure NEC's 1-m SIS on November 6-8 and 11 at NEC in Yokohama. He was joined by Spyak on November

11. Both the VNIR and SWIR CCRs were moved to MELCO on November 11 where Spyak measured the MELCO SIS from November 12-15 using the SWIR CCR. Preliminary results were presented in Japan during daily meetings and all preliminary data were again provided to C. Johnson. The stability and repeatability of the measurements of the two ASTER spheres was quite good.

VNIR CCR: The objective of this project is to design and build a 400- to 900-nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer is compared directly to NIST-calibrated and NIST-traceable standards of spectral irradiance. Biggar designed the radiometer with three silicon detectors in a "trap" configuration. Spectral selection is through interference filters, and two precision apertures determine the field of view. Heating the detector assembly, filters, apertures, and amplifier to a stabilized temperature, a few degrees above ambient, provides thermal control of the system. The system uses a high accuracy voltmeter connected via GPIB to digitize the amplifier output. A commercial datalogger digitizes ancillary information such as detector temperature, and controls the amplifier gain through digital output ports. This datalogger sends the serial digital data to an MS-DOS compatible computer.

Biggar did radiance calibrations of the VNIR radiometer on 30 July. His estimated uncertainties are less than 3% with respect to absolute using a NIST-calibrated irradiance standard. The results matched a calibration done earlier in the year to better than 0.5%. Biggar made multiple measurements of our 6-inch Spectralon SIS prior to, during, and after the trips to California and Japan mentioned above. These measurements show that the radiometer and sphere in combination have not changed significantly in responsivity and that the radiometer is repeatable. Biggar modified the 6-inch SIS shipping case to allow him to ship the docking station for the notebook computer to allow easier GPIB connections. He installed a GPIB card into the docking station for a more reliable connection to the VNIR CCR. E. Nelson continued work on the second version of the VNIR CCR.

For the measurements in Japan with the VNIR CCR, the NEC sphere was run at the 3 ASTER VNIR calibration levels (one for each band) and the band 1 level was repeated on November 11. The NEC sphere calibration values (radiance) were band averaged over the spectral bands of the UofA VNIR CCR. Those band-averaged results were compared to the measurements made by the radiometer. The results were consistent for all three bands. The general result was that the radiometer measurements were higher than the NEC values at short wavelengths and lower at long wavelengths. The ratios of the UofA radiances to the SIS calibration values from NEC ranged from 0.985 to 1.064 for all seven bands of the VNIR CCR and the three SIS output levels. However, for ASTER bands 1 and 2, which have the closest spectral match to the bands of the VNIR CCR, the UofA measurements agree with NEC values to better than 1% and the repeat measurements of the band 1 output level show repeatability in ASTER bands of better than 0.3% (0.58% was the worst case but this was for one of the VNIR CCR bands at a wavelength much shorter than the passbands of ASTER). For band 3, the NEC values are probably within 1.5% of what a radiometer with calibrations consistent with the UofA radiometer would measure (the NEC calibrations of the SIS are smooth and cover both of the UofA radiometer bands on either side of the ASTER band 3).

SWIR CCR: The objective of this project is to design and build a 1000- to 2500-nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer is compared to NIST-calibrated and NIST-traceable standards of spectral irradiance and pressed PTFE (Algoflon) targets. The system is designed around an InSb detector. Spectral selection is through interference and absorption filters, and the field of view is defined by a cryogenically-cooled baffle system. A chopper is used to optimize the signal-to-noise ratio.

The measurements made with the SWIR CCR at MELCO in Japan were for the four high-output settings of the sphere used to calibrate ASTER. The four settings arise because a different setting is used for bands 4, 5, 6, and 9 of ASTER. The SIS output was measured for all 9 SWIR CCR bands ranging from 1244 - 2403 nm (1646 nm, 2134 nm, 2164 nm, 2208 nm, 2263 nm, 2332 nm, 2403 nm, plus two shorter-wavelength MODIS bands). Here, only the results of the bands from 1646 - 2403 nm are discussed as they pertain to ASTER. The SWIR CCR signal-to-noise ratios were greater than 5500. The calibration values for the MELCO sphere were consistently 3% to 7.5% higher than those obtained with the SWIR CCR with the shorter wavelengths having the better agreement. Additionally, a spectral dependence was observed in the SIS output when changing the sphere output levels. Measurements indicate that this results from the bare aluminum aperture on the auxiliary sphere as it opened and closed to achieve the various output levels. It is estimated that this effect may be as large as 2% when comparing the measurements at 1646 nm and 2403 nm. To determine the sphere's repeatability, measurements were made for sphere-level 4 on three different days and for level 5 on two days. Results indicate that the repeatability was better than 0.5% for 2403 nm, and better than 0.4% for all other bands.

Spyak performed radiance calibrations traceable to NIST on the SWIR CCR to characterize the radiometer for the cross-calibration experiments. The estimated error in this calibration is less than 4%. Spyak characterized the SWIR transfer radiometer using the 40-inch spherical integrating source (SIS). These included measurements to examine stability, repeatability, band-to-band consistency, signal-to-noise ratio, sphere uniformity, sphere drift, and radiometer interactions with the sphere. He also viewed the 6-inch SIS to measure the stability and repeatability of this source. C. Burkhart made a mount for the tripod assembly to hold the 6-inch SIS in front of the SWIR CCR. This allows the SIS to be viewed in a repeatable fashion for use during calibration experiments in the field to monitor the radiometer's operation. Spyak reduced the in-band bandpass filter data. A few filters are slightly out of specification, but the effect of this is not expected to be significant.

Spyak performed two independent BRF measurements of a barium sulfate, field-reference panel using the SWIR CCR. Measurements were made with nine bandpasses over the spectral range from 1244 - 2403 nm. Results from two of the bands are shown in Figures 1 and 2, where the x-axis is the incident angle and the detector view is always normal to the sample. As can be seen in the figures, the two measurements are in excellent agreement for both bands. All of the other bands show similar agreement indicating excellent precision.

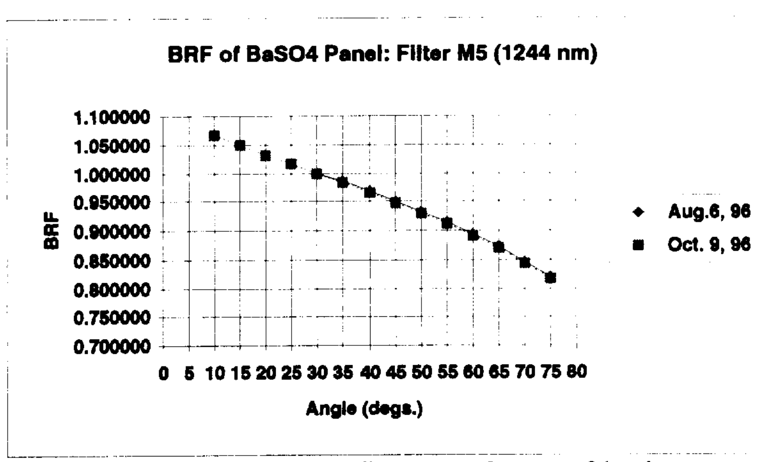

Figure 1. Bi-directional reflectance factor of barium sulfate panel determined from SWIR CCR data for 1244 nm.

Spyak completed a draft of a paper on the SWIR CCR and sent it to Cincinnati

Electronics (the InSb detector manufacturer) for review. E. Nelson prepared the shipping containers for the SWIR CCR. Spyak returned the shipping case for the SWIR CCR's tripod that arrived damaged and had it repaired. J. LaMarr modified the data collection software for the radiometer. Spyak reduced the data from both the US and Japan experiments. He evaluated the SWIR CCR after its return from Japan and it appears to be working well.

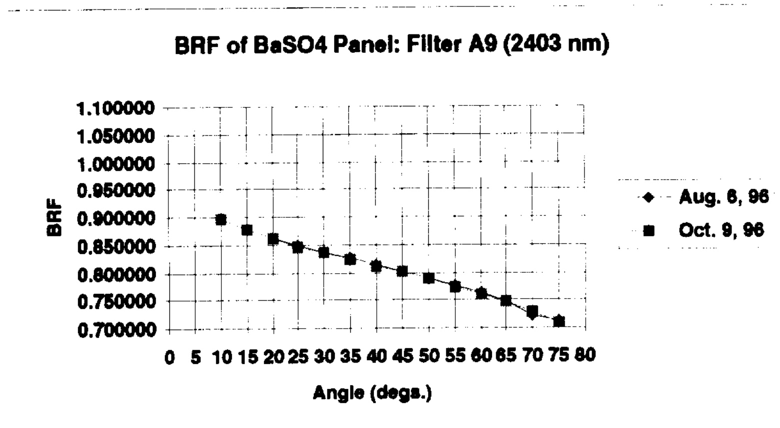

Figure 2. Bi-directional reflectance factor of barium sulfate panel determined from SWIR CCR data for 2403 nm.

BRDF Meter: The objective for this task is to design and construct a device, and develop software for measuring the directional reflectance and inferring the bi-directional reflectance distribution function of the ground. The basic design incorporates a fisheye lens, a CCD-array detector, and interference filters for spectral selection.

P. Nandy tested the BRDF camera's spatial uniformity and overall system performance using the fisheye lens and 40-inch SIS. A variety of look angles, bands, and camera orientations were used. The measurements showed a distribution of circular dark spots that Nandy determined were not due to the SIS or the fisheye lens. Further testing with a standard Nikon 55-mm lens also showed a bright spot in the center of all images. Nandy sent the camera to Photometrics for cleaning and to pump and bake the detector array. The camera was tested after being returned and all of the dark-spots had disappeared. The central bright spot was found to be an artifact of the 55-mm lens and the spot is not apparent in the fisheye data.

Thome used the camera during a White Sands trip in September to collect several sets of data. These data were used in an attempt to retrieve the bi-directional reflectance factor along the azimuth plane of the cross-track direction of the SPOT-HRV sensors. An example of one of the images is shown in Figure 3. These data were collected at 6:38 am MST on September

6. The striped board in the image is for reference purposes and is aligned along the cross-track direction of the SPOT satellite. The dark stripes on the board are 10 cm wide while the bright stripes are 20 cm. The bright area near the shadow of the camera head is due to a white box from another piece of equipment. The increase in signal as the system views towards the backscatter direction is clearly evident. Work is currently being done to remove detector and optical effects from the data set. However, the spatial non-uniformity of the White Sands site is also obvious in the figure and this caused the data to be too "noisy" to accurately retrieve the bidirectional reflectances factor. A possible solution to this problem is to raise the camera to a higher height (it was operated at 1.5 m for this experiment) and to perform spatial averaging. The group is currently evaluating how high the system should be mounted to still allow easy operation of the system and overcome the spatial homogeneity problem.

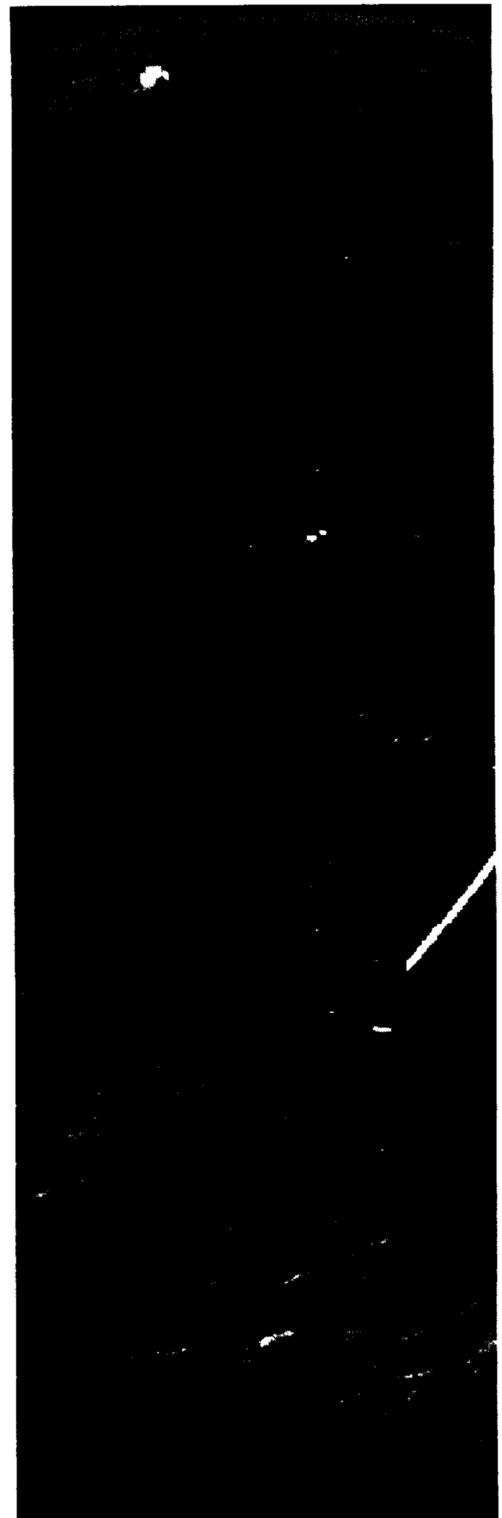

Figure 3. BRDF meter image from White Sands at 6:38 am MST on September 6, 1996

Diffuse-to-global meter: The objective of this task is to design and build an instrument to collect diffuse-to-global irradiance data. By comparing the diffuse downwelling irradiance to the global (direct plus diffuse), an improvement to the atmospheric correction may be made which reduces the uncertainty of the reflectance-based method. Currently, global irradiance data are collected using a radiometer viewing a reflectance panel and diffuse data are collected by manually positioning a parasol to shade the panel. The diffuse-to-global meter will collect these data automatically and more repeatably.

B. Crowther continued work on the diffuse-to-global meter. Crowther sent the diffuse-to-global meter's computer for repair and received it back. Crowther received repaired stages from Aerotech and ordered an additional fiber optic cable for the LiCor and two travel cases for the diffuse/global equipment. The spectrometer and motor control program are now working and he linked the Aerotech and the Greenleaf RS-232 libraries. C. Burkhart completed a rough model of the occultor that Crowther tested for vibration. Burkhart completed the machining of the manual version of the diffuse-to-global meter for the White Sands field campaign in November. He is continuing to work on the final version of the cosine receptor for the instrument.

Crowther conducted calibration experiments to determine the responsivity of the LiCor detector as a function of temperature and the spectral calibration of the LiCor. The sources used for the spectral calibration were the Optronic monochromator, a HeNe laser, and three atomic line sources. Initial results indicate that the bandpass of the LI-1800 is quite close to the 12-nm figure specified by LiCor. The angular response tests used data collected on Mount Lemmon and at White Sands. Data were collected with three candidate knife edge apertures for the sphere. Two of the three days of data collected during the White Sands campaign in early September were processed. The data from the remaining day, collected with the polished aluminum knife edge, were not processed because of data collection problems. Both the roughened aluminum and duraflect knife edges produced results that agree well with the Monte Carlo modeling of the sphere collector. The main differences appear at zenith angles greater than 70 degrees.

Crowther also made laboratory measurements of the angular response of the sphere collector for three candidate knife edges. The results of these laboratory measurements are shown in Figure 4 for the Duraflect knife edge that was selected as the best choice. The graph also shows the Monte Carlo simulation results for the sphere collector as well as the output of a ten-term cosine series fit to the laboratory data. This fit reproduces the laboratory data to better than 0.5% and will be used to account for the angular response of the system in the data processing.

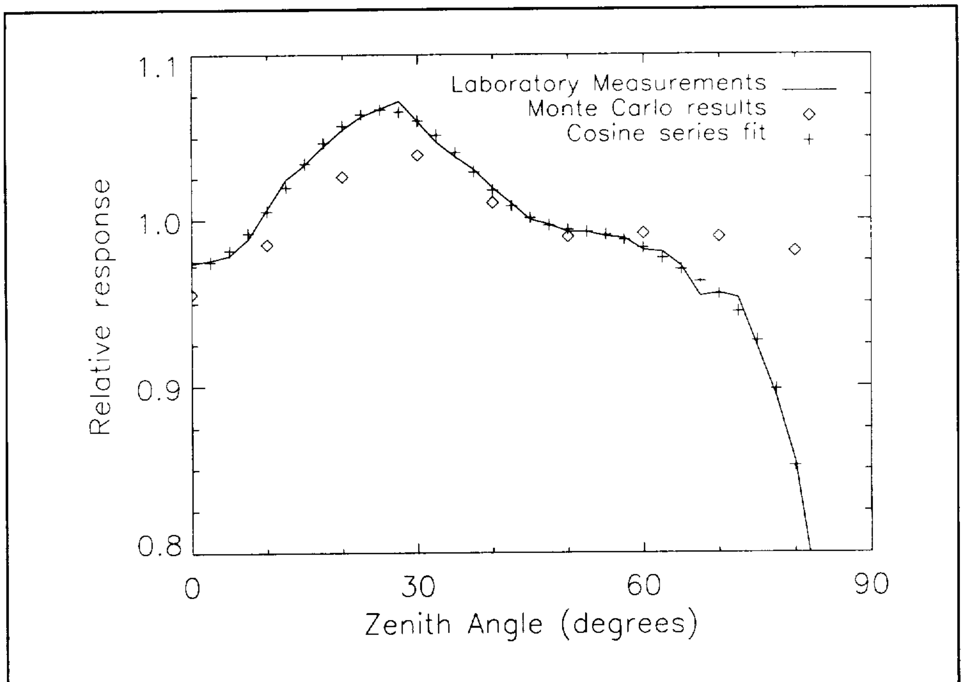

Figure 4. Comparison of predicted angular response of the diffuse-to-global based on Monte Carlo modeling of the sphere collector to that measured in the blacklab.

<u>TIR field radiometer</u>: This part of our work has seen several modifications. The original objective was to construct cross-calibration radiometers to cover the 3000- to 14500-nm spectral region, test these radiometers, and write control and data acquisition software. This plan was dropped because of budget reductions. It was decided to attempt to construct a field-compatible TIR radiometer which could also operate as a transfer radiometer. This radiometer, designed for precision only, would cover 8,000 to 14,500 nm. This work was delayed because of budget constraints. We have since modified our approach and intend to build/purchase a single-band radiometer that can be calibrated to high accuracy. This radiometer will be used for the vicarious calibration of a single band of both MODIS and ASTER. The intent is to use this single-band calibration to validate the results from the MODIS and ASTER onboard blackbodies. We are now presently evaluating commercially available systems to determine if they can meet our needs for this purpose. In addition, we continue to evaluate several other TIR radiometers.

Sicard cleaned the objective element of the Cimel TIR radiometer. He received software from Cimel to collect 16 data points per second and is still evaluating this software and data collection mode. Sicard wrote software to account for filter-spectral transmittance when computing the responsivity of Cimel TIR radiometer, and this was used to compute a new set of calibration equations for the radiometer. Sicard computed the noise-equivalent delta temperature using two independent methods and found similar results. He performed another calibration of the radiometer for a variety of temperatures between 263 and 353 K. He found a first order polynomial relating DN and radiance, a third order polynomial relating DN and temperature, and a third order polynomial relating the change in DN for a 1 K temperature change as a function of temperature. He also computed the noise-equivalent delta temperatures and radiances as a function of temperature. The results from this work agree to better than 0.4% compared with the calibration data from last March.

Sicard developed software to incorporate spectral emissivity in the data processing. He also developed software to compute the band-integrated transmittance of the system's filters. Sicard received Jornada ground data and emissivity measurement from ASTER Science Team member, T. Schmugge and Railroad Valley emissivity data from S. Hook of JPL. He also received Lunar Lake TIR data from H. Tonooka of the ASTER Science Team. Sicard reprocessed the Lunar Lake, Lake Tahoe, and Jornada data with the updated software and emissivity data and sent the Lunar Lake results to Hook and F. Palluconi of JPL. The Lake Tahoe data shows good agreement between the four bands of the Cimel. The Lunar Lake data shows the site to be spatially uniform. The Cimel data also agree well qualitatively with data from the Everest transducer and the system operated by the Japanese. The quantitative agreement is not as good with an approximate bias of 2K between the systems. The source of this difference has not been identified.

Sicard presented preliminary results at a meeting held by Cimel on July 26th, in Avignon, France. In the presentation, Sicard showed comparisons with measurements of several surfaces made with an Everest IRT at Jornada. Comparison data from Lunar Lake were also shown. Sicard concluded that the CIMEL is stable for ambient temperatures between 10 and 40°C, the response for the four filters shows good agreement, and the calibration done in the lab is different by 1% in radiance from that determined from field measurements. Sicard suggested that Cimel install an internal blackbody, develop a temperature-controlled box, increase the data acquisition rate, and improve the accuracy of the detector thermometer.

Sicard, Spyak, and Zalewski made plans for a field campaign to Jornada Experimental Range near Las Cruces, New Mexico that was organized by ASTER Science Team member, T. Schmugge, and took place September 10-12. The results from the September Jornada experiment show better agreement between the Cimel and Everest, mostly due to the low temperatures, cloudy skies, and wet surface.

Calibration Laboratory: The objective of this project is to develop a calibration laboratory that will provide the necessary high-radiometric-accuracy standards and characterization set-ups for 1) the cross-calibration radiometers and 2) the field and aircraft radiometers needed for preflight algorithm and code validation and the actual in-flight calibration of the EOS multispectral imaging sensors beyond 1998.

Our blacklab facility was used by representatives from UCLA to characterize the aluminum diffuser for PMIRR (Mars Observer replacement instrument). Biggar modified hardware and software in the blacklab to prepare it for use by the UCLA personnel. In response to problems with the blacklab computer, Biggar and T. Mitchell began modifying the blacklab software to operate on a new Pentium class computer. They determined how to move a linear stage with the U100 controller via the GPIB interface. There are still some minor difficulties in controlling the Unidex stages in the blacklab through the GPIB interface, but progress has been made. Mitchell derived center wavelengths and bandpasses of the interference filters for the blacklab radiometer using the full-width-half-maximum and moment methods.

Spyak sent Ultra-Pol (black cloth) samples to J. Young of SBRS for testing. Spyak evacuated the InSb dewar for the Optronic monochromator. Spyak ordered a new laser for the blacklab. P. Spyak received a 1000-W irradiance standard, black material, and miscellaneous hardware for the calibration laboratory. Nelson rebuilt the blacklab VNIR radiometer detector assembly to temperature control it and to reduce noise by putting the amplifier in the detector assembly.

Spyak and J. LaMarr began a study to determine the effects of atmospheric absorption in laboratory measurements. The initial step in this procedure is to determine the reliability of using MODTRAN in predicting the atmospheric absorption over short horizontal path-lengths of perhaps a few meters. Previous verifications of MODTRAN have primarily been performed over long path lengths (often 1000 m or more), so, the reliability in using MODTRAN to predict absorptions in laboratory is only conjecture. Using a spectroradiometric system, and measurements of humidity and temperature, spectral-atmospheric-transmittance measurements were made over several atmospheric absorption bands and the data compared to that predicted by MODTRAN. Figure 5 shows the results of one of these comparisons for the water vapor absorption band in the spectral range from 1330 to 1500 nm. The water vapor amount used in the MODTRAN run was that determined by a humidity sensor placed inside the monochromator. We attempted to simulate the spectral properties of the monochromator measurements (center wavelength and slit width) as well as possible, but there are still some differences in the center wavelengths because MODTRAN computes transmittance in even wavenumber intervals while the monochromator collects data at even wavelength intervals. Even with these differences, the results of the comparisons are quite good.

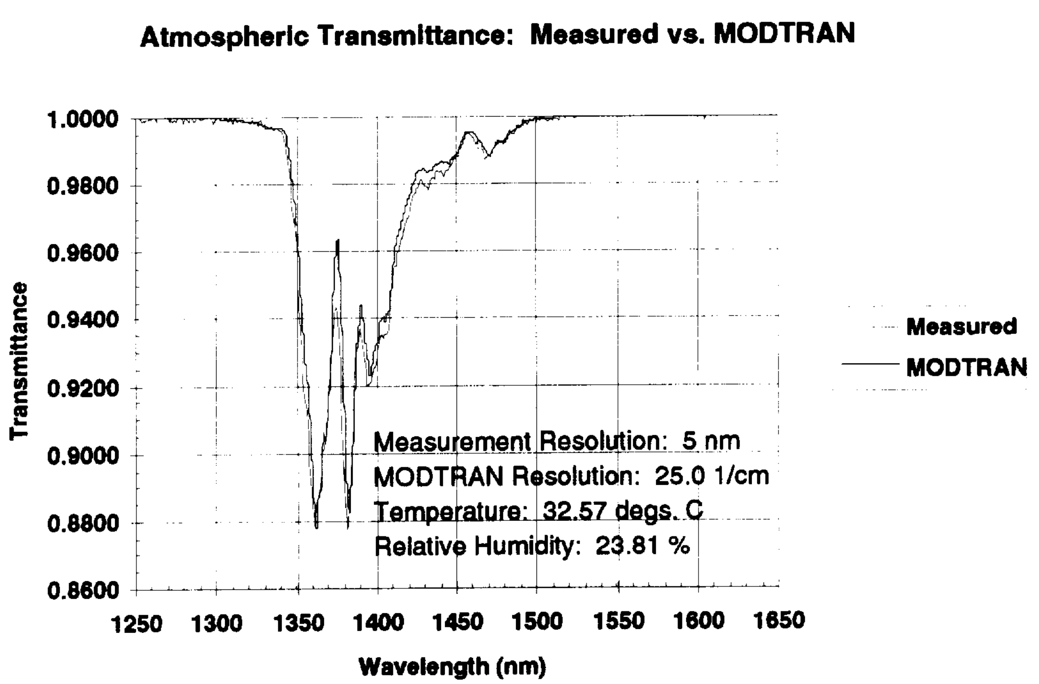

Figure 5. Comparison of measured atmospheric transmittance within the Optronic monochromator and predicted transmittance computed by MODTRAN.

Algorithm and Code Development: Currently, several algorithms exist to perform our calibration work. The RSG has applied these algorithms as FORTRAN programs which are neither user friendly nor efficiently linked together into a single package. The task objective is to convert these existing codes into ANSI standard C in a user-friendly package with rules-based decision making in the package. The group is now also involved in the atmospheric correction of ASTER data in the solar-reflective portion of the spectrum

R. Parada adapted radiative transfer code software written in France to run on our computer system. He found a bug in the wave-slope modeling in the code and fixed this. He used this code for a sensitivity analysis of the radiance-based approach for vicarious calibration using both Lake Tahoe and the open ocean. Parada received several improvements of successive orders radiative transfer code from R. Santer. Parada completed a first attempt at the calibration of AVIRIS data from June 1995 corresponding to the SeaWiFS wavelengths and summarized the results of this work in the EUROPTO paper that Thome presented.

K. Scott continues development of the cross-calibration software that is being written in IDL. Currently, most of the development centers around the creation of a user interface to the French radiative transfer program 6S. The input module is an IDL widget (graphical user interface) that provides the user with most of the input options available in 6S. In addition, spectral reflectance functions for Lunar Lake, Railroad Valley, and White Sands are included as defaults that the user can elect. After data have been entered, the program writes both a user readable output file and a 6S readable file, and then calls the 6S program. The module will be integrated as part of the cross-calibration software program, but will also be operable as a stand-alone module.

P. Nandy wrote IDL software that streamlines the ASD FR data processing routines. The code strips and decodes the header segments of multiple data files and graphs the data in a format similar to that of the PC-based ASD software. The software also processes the header information and spectrometer data from multiple ASD files and compiles them into a single file readable by our reflectance-retrieval software. The software allows the user to select a particular set of ASD data files, converts these to the appropriate format, and then initiates the reflectance-retrieval software.

P. McIntosh developed software to compute band-averaged surface reflectance given the spectral response of a radiometer and hyperspectral surface reflectance data. This software will be used for comparing the reflectance derived by the four-band Exotech and seven-band MMR radiometers to the higher spectral resolution data from the ASD FieldSpec FR.

Field Experiments and Equipment: The objectives of the field experiments are to test new equipment, determine needed improvements, test retrieval algorithms and code, and monitor existing satellites in much the same way as we shall for EOS sensors.

C. Gustafson computed image registration and digitization errors in cross-calibration data using the TM imagery from White Sands from October 1994. She found several 2-km by 2-km areas where there is no change in a calibration coefficient derived from cross-calibration using data that is misregistered by as much as 0.5 km. Several 4-km by 4-km areas were found where the error is less than 1% for the same misregistration and 10-km by 10-km areas where the error is less than 3%. Similar results were obtained using HRV data from the same time period.

LaMarr reviewed what is needed to upgrade the autotracker. He designed a mount for testing the autotracker filter encoding and completed ND filter measurements and out-of-band measurements on spectral filters. Biggar and Crowther replaced the controller board in the Helios data logger. Spyak ordered and received a Spectralon panel for field work, and four shipping cases for field reflectance equipment. R. Kingston developed software to allow surface reflectance data collection with our Polycorders.

Thome completed the processing of the reflectance-based data from the First Joint Vicarious Calibration Campaign at Lunar Lake. Predicted radiances at the top of the atmosphere have been determined at 1-nm intervals from 350 to 2500 nm for all data sets from June 1, 2, 3, and 4. The processing was done using both MMR and FieldSpec derived reflectances and for all targets of each data set. This amounts to a total of 66 sets of radiative transfer output at the above wavelengths.

Parada planned and coordinated a field campaign to Lake Tahoe that took place July 21-31. The goal of the campaign was to collect data to validate the use of the successive orders radiative transfer code over the lake and the collection of data for the calibration of AVHRR (NOAA-14). C. Curtis, LaMarr, Nelson, Parada, and Thome participated. Biggar, Crowther, Parada, Spyak, and Thome traveled to White Sands to collect data for several SPOT-2 and -3 calibrations September 4-9, and Thome processed the data from this trip. Crowther, M^{c}Intosh, Nandy, Parada, and Thome traveled to White Sands November 14-16 to calibrate Landsat-5 TM and SPOT-2 HRV. The campaign was planned by Crowther and was to be used to test the manual version of the diffuse-to-global meter. Unfortunately, poor weather prevented any usable data from being collected. Biggar and Crowther traveled to White Sands December 12-16 in an effort to test the diffuse-to-global instrument. The two, assisted by WSMR personnel, collected data for two simulated SPOT overpasses on December 13 and 16, and an actual Landsat-5 overpass on December 16.

Crowther traveled to Wilcox Playa to collect reflectance data to evaluate the potential of the site for calibration work. The playa is about 130 km southeast of Tucson. Crowther found the reflectance of the site is only about 0.20 to 0.25 in the visible region but is about 0.45 at 1.7 microns. The site is not very uniform but is large enough to be seen by large footprint sensors. Further work is planned to better quantify the spatial uniformity and spectral characteristics of this site.

K. Thome collected several days worth of solar radiometer data with the 10-channel instrument to evaluate its calibration. He verified that the system has continually degraded since last March. He attempted to get the Cimel solar radiometer operating on the roof of the OSC building but was unable to get the transmitter operational. The radiometer itself operated properly throughout most of November. Thome packed up the Cimel solar radiometer and sent it to GSFC where the filters will be replaced with new IAD filters, the telescope will be replaced to reduce the out-of-field response of the system, and the system will be calibrated using the GSFC SIS. They will also attempt to fix the transmitter. The system should be returned in early February.

Faculty, staff, and students: The personnel presently associated with the RSG are as follows. Faculty: Biggar, Slater, Spyak, Thome, and Zalewski. Staff: Burkhart, Kingston, Nelson, Recker, and Sicard. Students: Crowther* (Ph.D.), Gustafson (MS), LaMarr (Ph.D.), M^{c}Intosh (undergraduate), Myers (undergraduate), Nandy (Ph.D.), Parada* (Ph.D.), Scott* (Ph.D.), and J. Walker* (Ph.D.). Those with an asterisk following their names have passed the Ph.D.

Preliminary Examination and are mainly working on their Ph.D. research. Crowther has a NASA Fellowship under the Graduate Student Research Program, and Parada has a NASA Global Change Fellowship. Gustafson, Scott, and Walker are independently funded and the rest are supported by this and other contracts.